Cloud Radiative Effects associated with MODIS Regimes of Regimes

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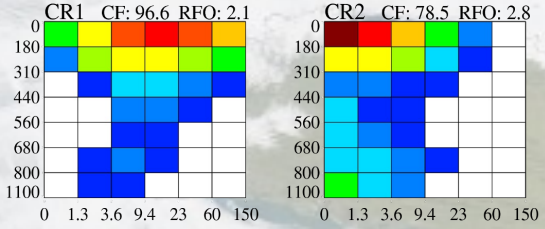
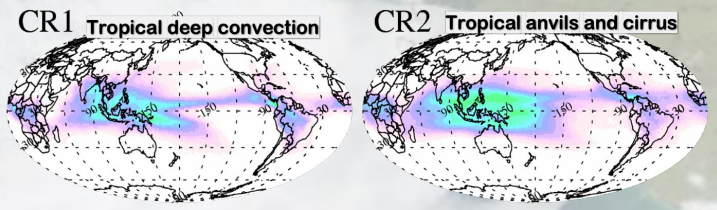
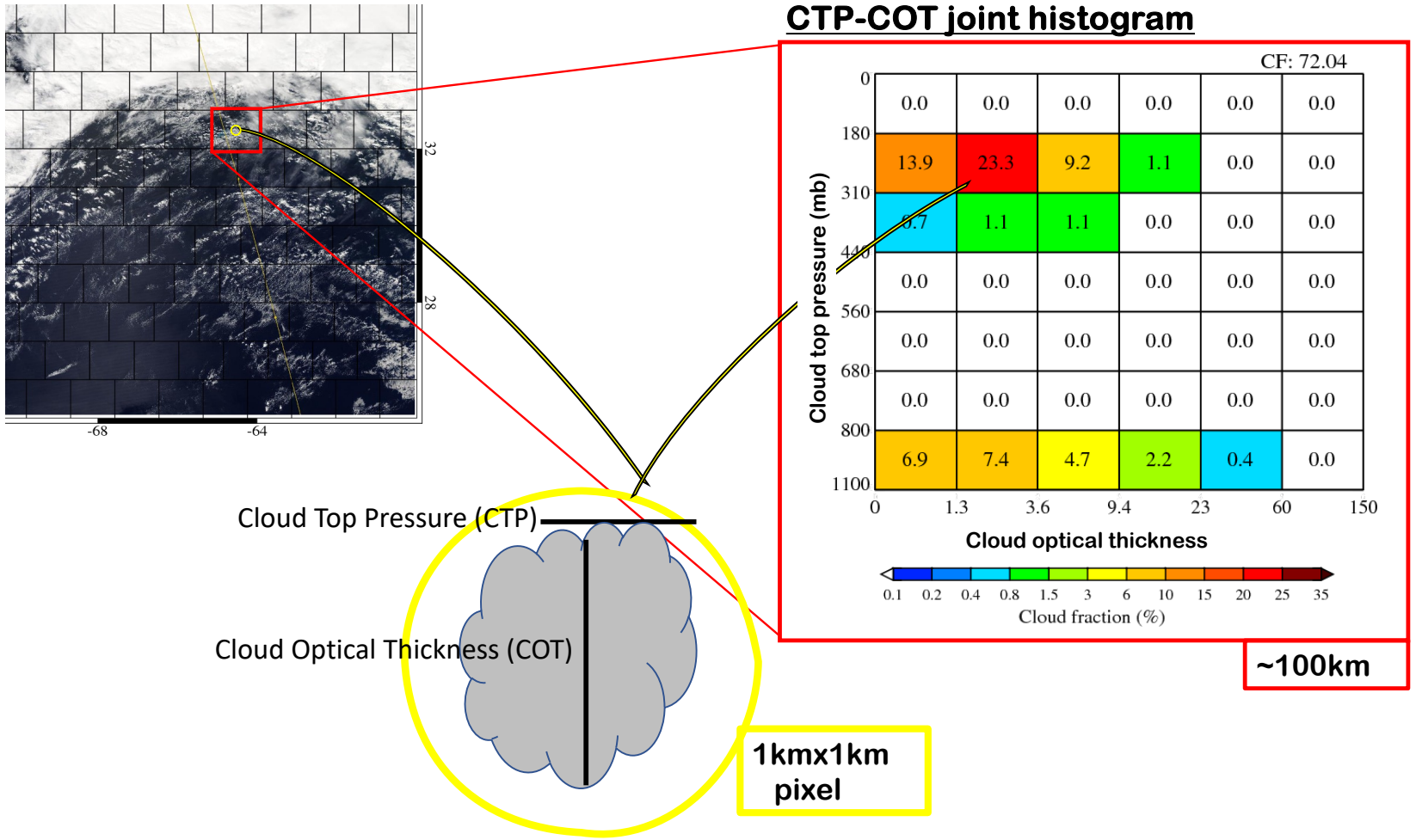
Characterizing and classifying cloudiness at monthly or longer temporal scales





- At meso-scales ~100 km the concept of “Cloud Regimes” or ”Weather States” was found to be useful in characterizing the mixture of cloud types occurring during a day.
- But what about over a month or longer periods?
  - Mean cloud properties conceal the underlying cloud variability
  - Cloud variability can be described via histograms of cloud properties
  - But these appear less and less distinct between regions the longer the temporal scale (consider: likelihood of an overcast grid cell in a day vs month)
  - Classification of monthly histograms (e.g. via clustering) fails.
- Here we are looking into a new approach: “Regimes of Regimes” (RORs)
  - *Classifying the monthly mixture of CRs at meso-scales*

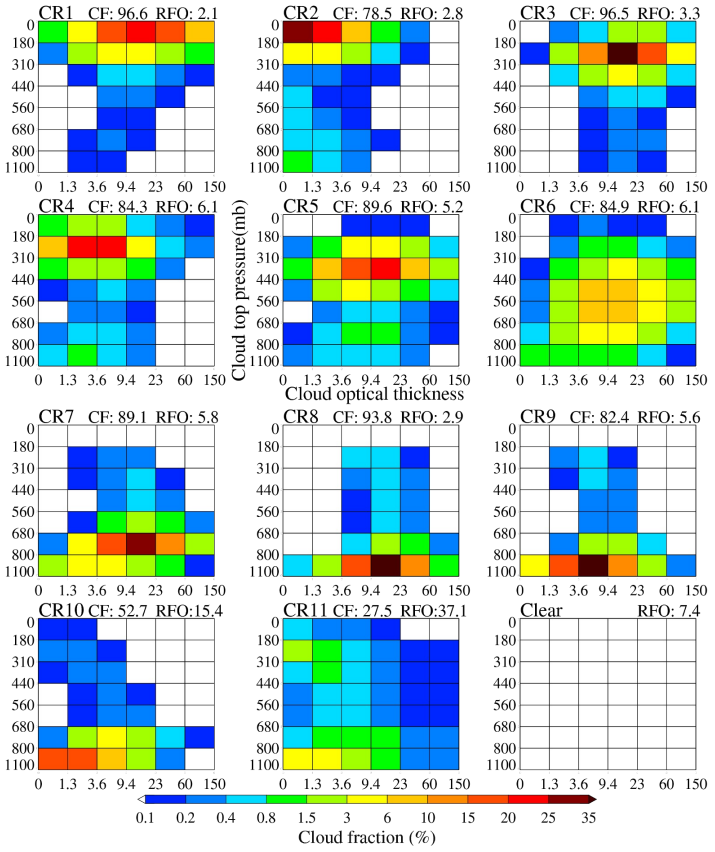
MODIS daytime joint histograms



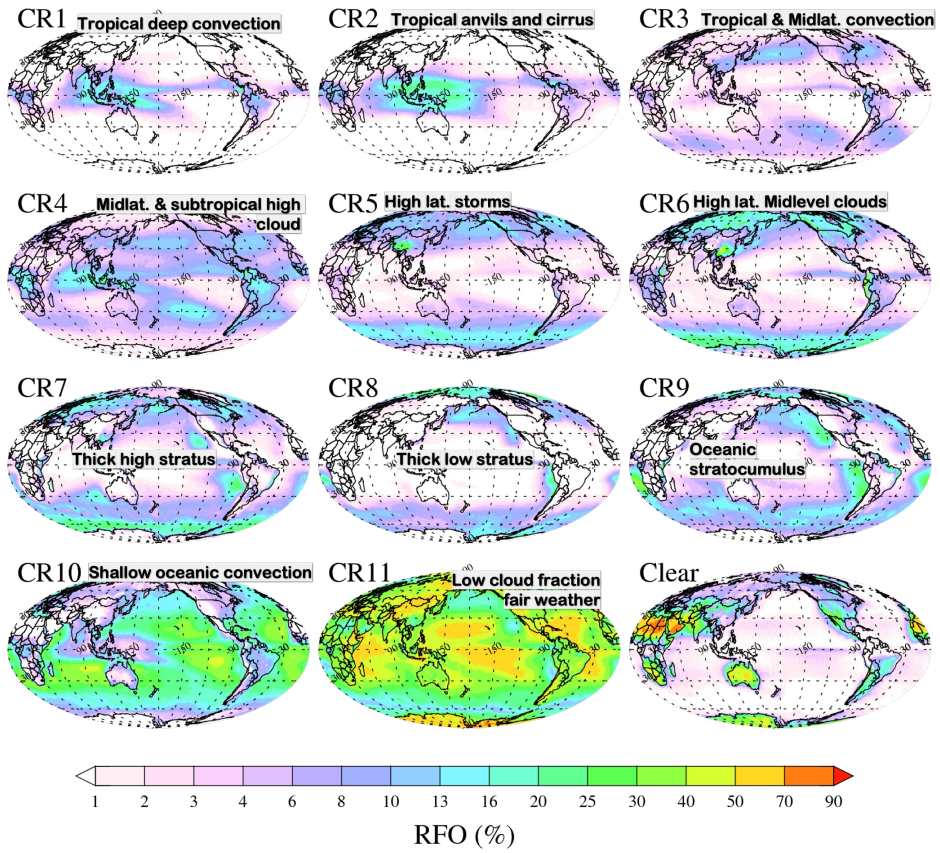
✓ Normalized fraction of MODIS pixels within a 1deg grid cell whose *daytime* CTP and COT values fall within one of 42 bins defined by predetermined CTP-COT pairs

MODIS daily Cloud Regimes (CRs)

- **CTP-COT joint histograms from MODIS L3 cloud products (MOD8/MYD08)**
- **JAN 2003- DEC 2022**
  (can be extended to present)
- **Cloud property retrieved by two MODIS sensors onboard Terra and Aqua satellites.**



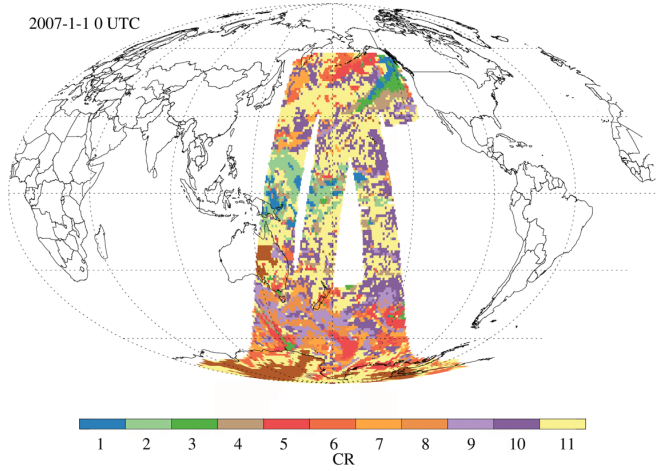
Global means (centroids) of all 2003-2019 joint histograms assigned to the 11 MODIS CRs



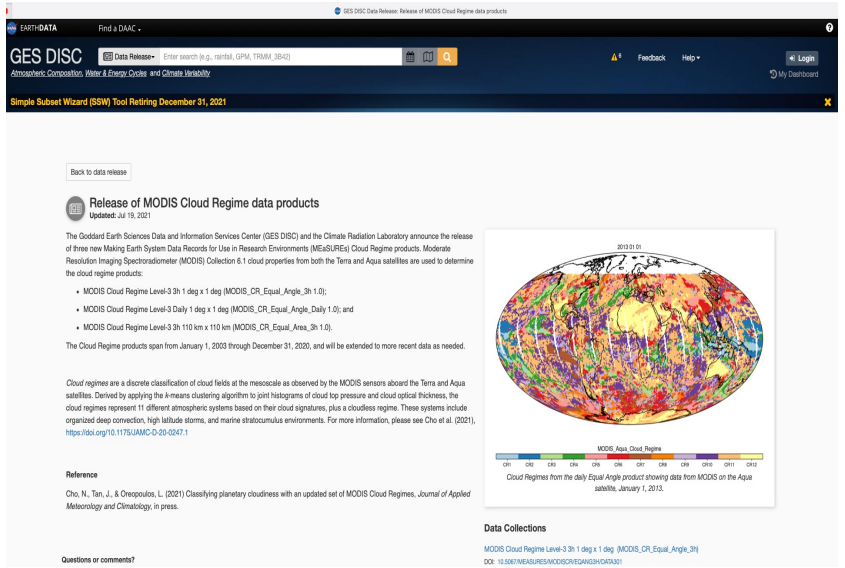
Maps of the multi-annual relative frequency of occurrence of MODIS CRs

Cho et al., 2021

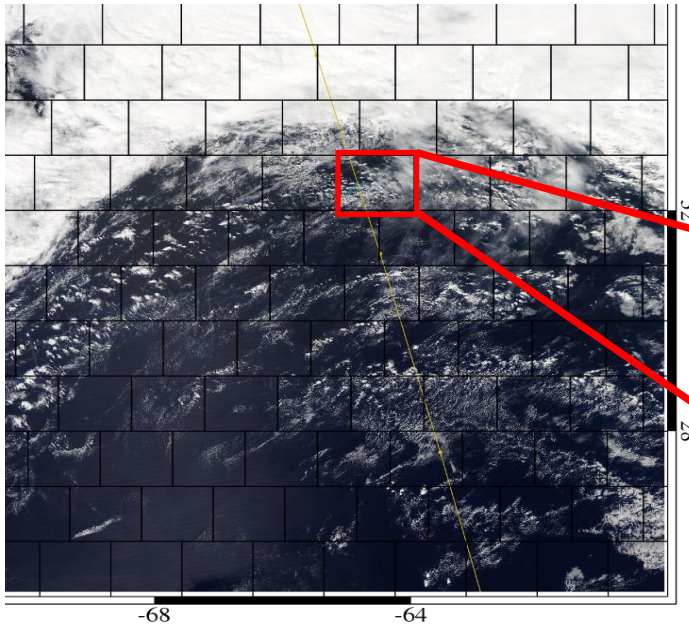
Daily geographical distribution of CRs



Data available at GES DISC

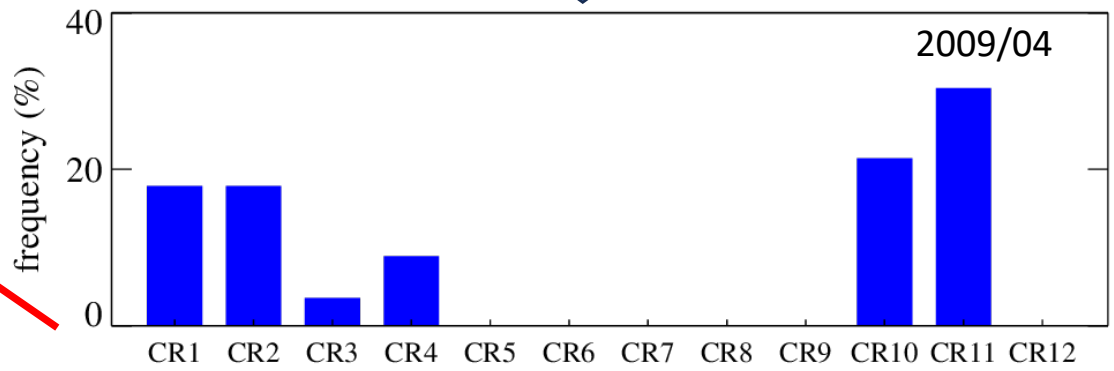


MODIS Regimes of Regimes (RORs): Derivation



APRIL

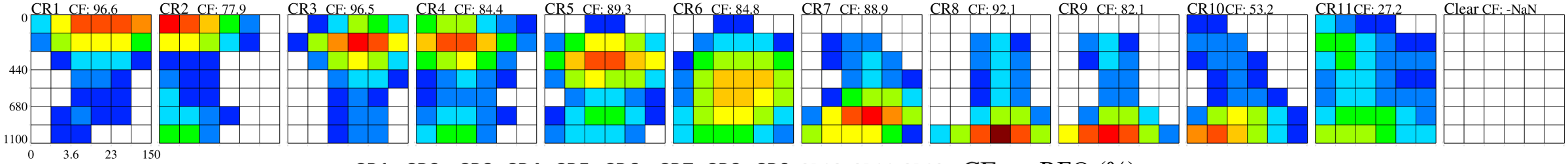
	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Aqua CR		10	2	2	1	10	10	10	3	10	----	11	2	11	2	1	11	10	1	4	4	11	10	10	10	2	----	1	11	4	2
Terra CR		11	2	--	4	11	11	11	1	11	----	11	11	2	1	2	11	10	1	---	4	11	10	10	11	11	----	1	2	3	11



- ✓ Build relative frequency of occurrence (RFO) histogram of daily CRs over a month (~15 million data points)
- ✓ Apply k-means clustering on the histograms to sort/classify into groups of alike histograms

→ Regimes of Regimes (RORs)

MODIS RORs: Definition



		CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10	CR11	CR12	CF	RFO (%)
Convective lifting	ROR 1	11.8	13.8	4.4	13.3	2.4	3.3	0.8	0.1	1.1	7.8	39.7	1.6	59.1	8.0
Middle latitude oceanic storms	ROR 2	0.5	0.3	5.5	5.3	9.6	7.1	9.2	10.9	15.6	15.9	18.9	1.2	69.7	15.2
High latitude midlevel clouds	ROR 3	0.5	0.1	3.2	2.1	12.0	20.8	20.2	6.7	7.0	8.5	17.4	1.3	73.0	9.8
Continental high latitude and polar environment	ROR 4	0.4	0.2	2.9	4.1	8.2	12.9	6.8	5.3	4.8	5.0	42.0	7.4	54.1	19.6
Low marine cloud environment	ROR 5	0.9	1.7	3.1	6.4	3.5	3.0	6.7	1.8	7.8	31.0	32.2	2.1	55.4	14.0
Subtropical convection and low cloud environment	ROR 6	1.3	3.3	1.7	5.6	1.8	1.9	2.2	0.4	2.2	23.8	52.8	3.1	44.5	11.2
Suppressed fair-weather	ROR 7	0.5	0.9	0.7	2.4	3.1	6.5	1.5	1.8	1.1	2.3	66.0	13.3	35.2	14.9
Arid environment	ROR 8	0.1	0.6	0.6	2.3	1.7	2.7	0.7	0.2	0.4	1.4	35.1	54.1 clear	18.4	7.2

tropical anvils/Cb's

Midlat/tropical storms midlevel clouds

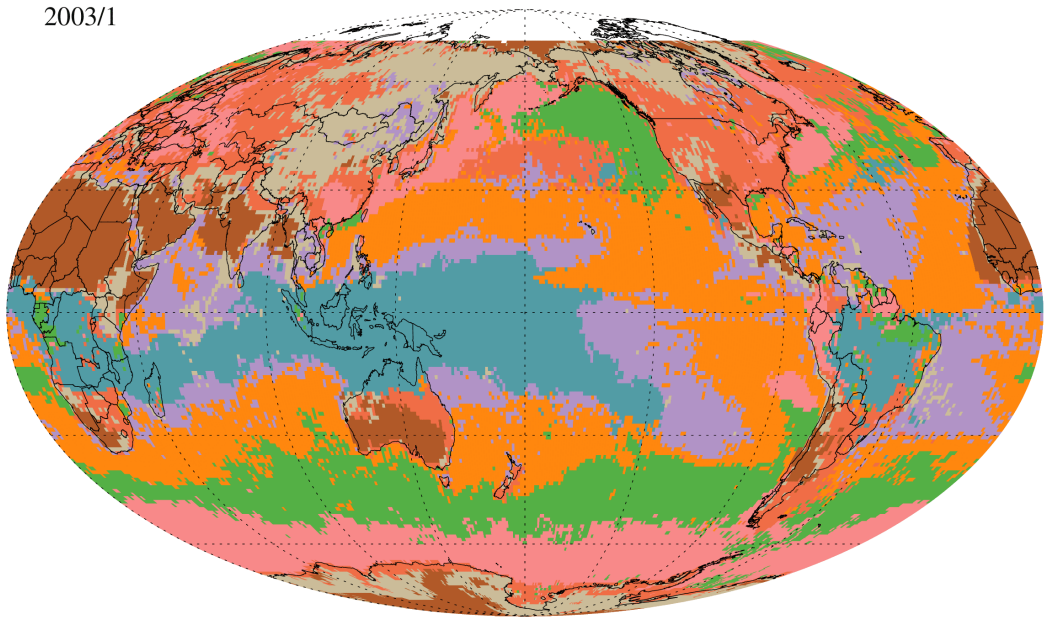
Low cloud mixtures

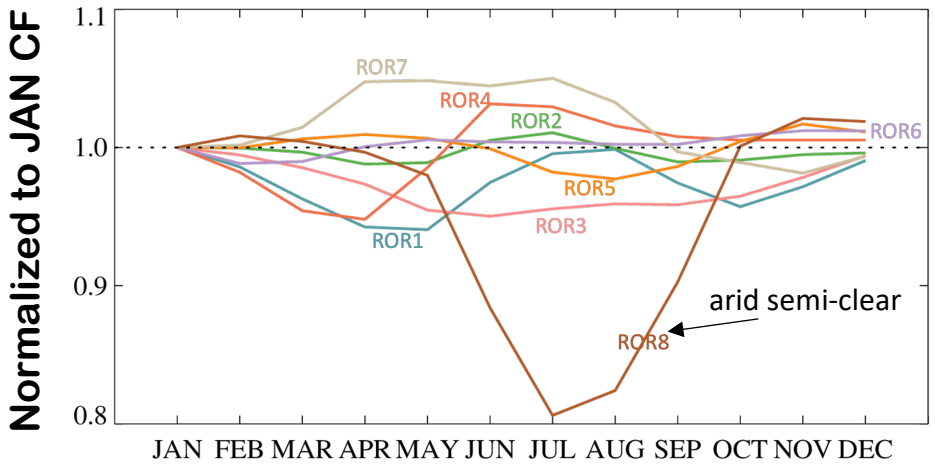
low CF mixture

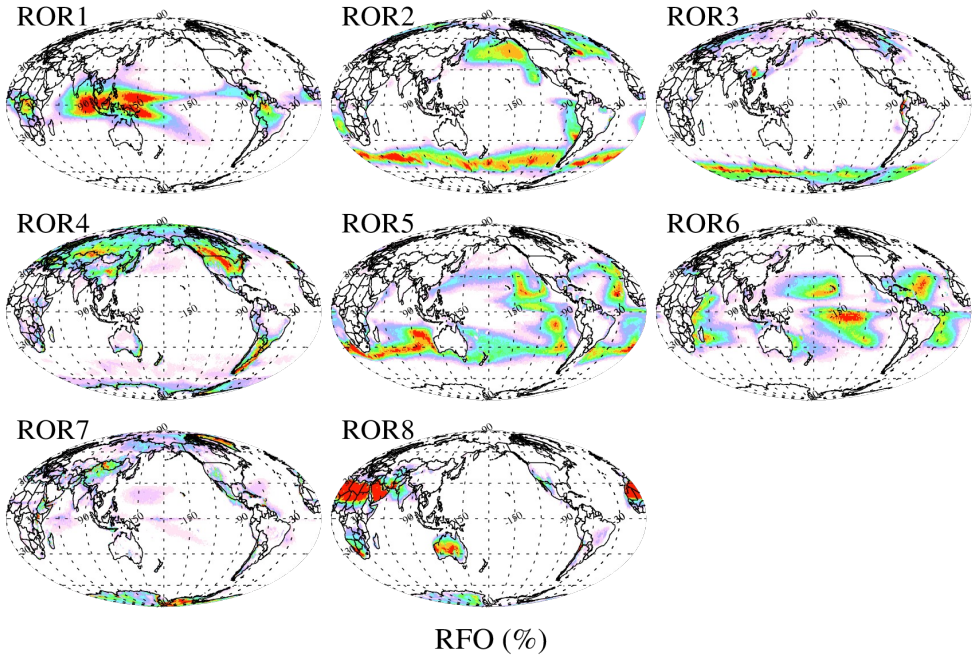
- Numbers show CR percentage contribution to ROR
- Colors show how CR population within ROR compares to climatology
  - ✓ red indicates more than climatology
  - ✓ blue indicates less than climatology

MODIS RORs: Variability

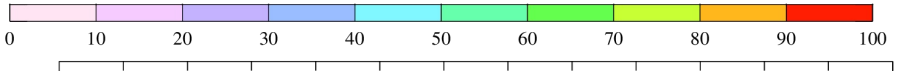
Seasonal ROR snapshots

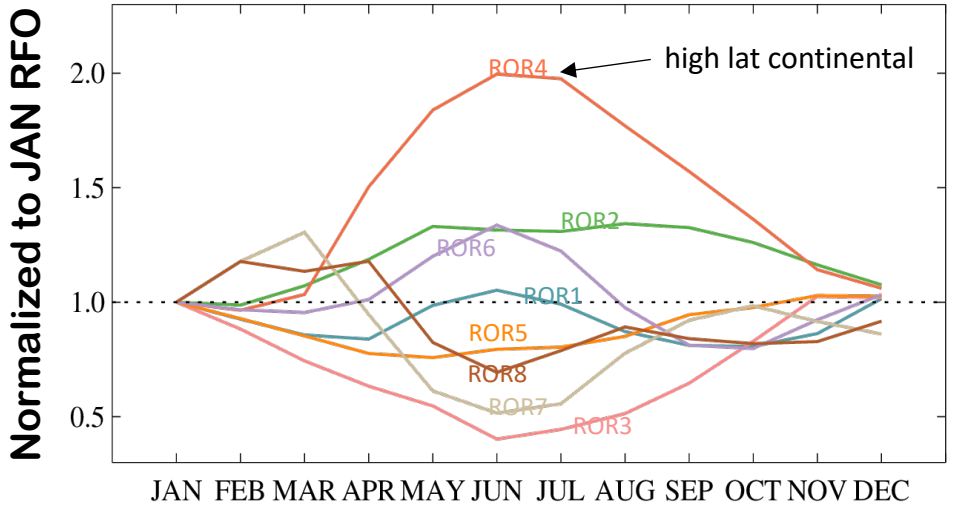






Multi-annual occurrence frequency (RFO)

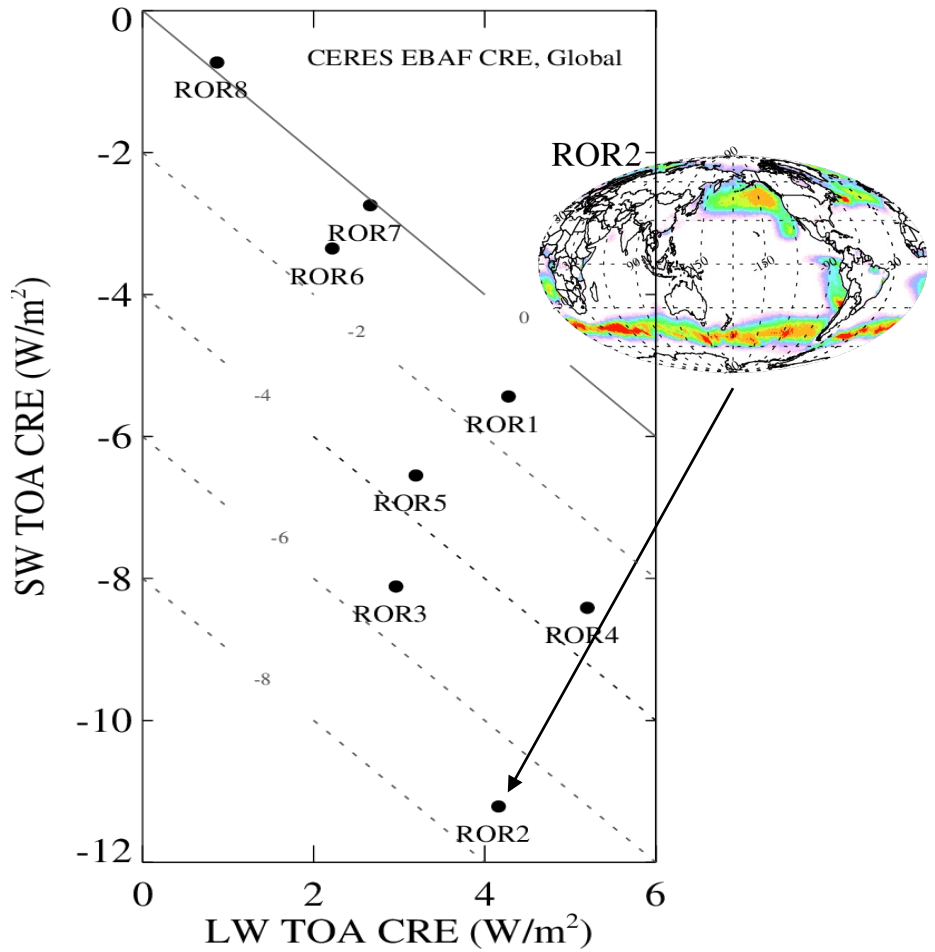


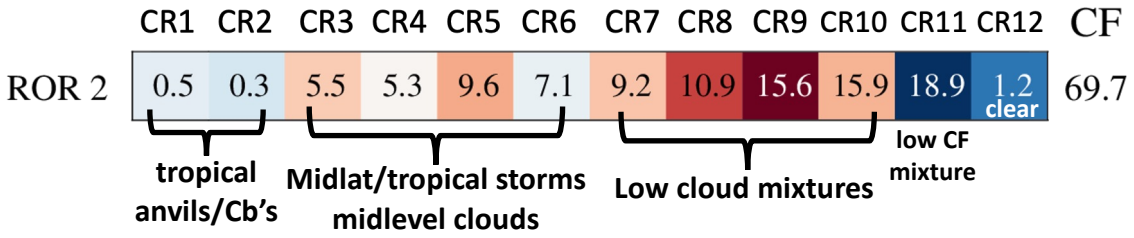


Application: CRE analysis

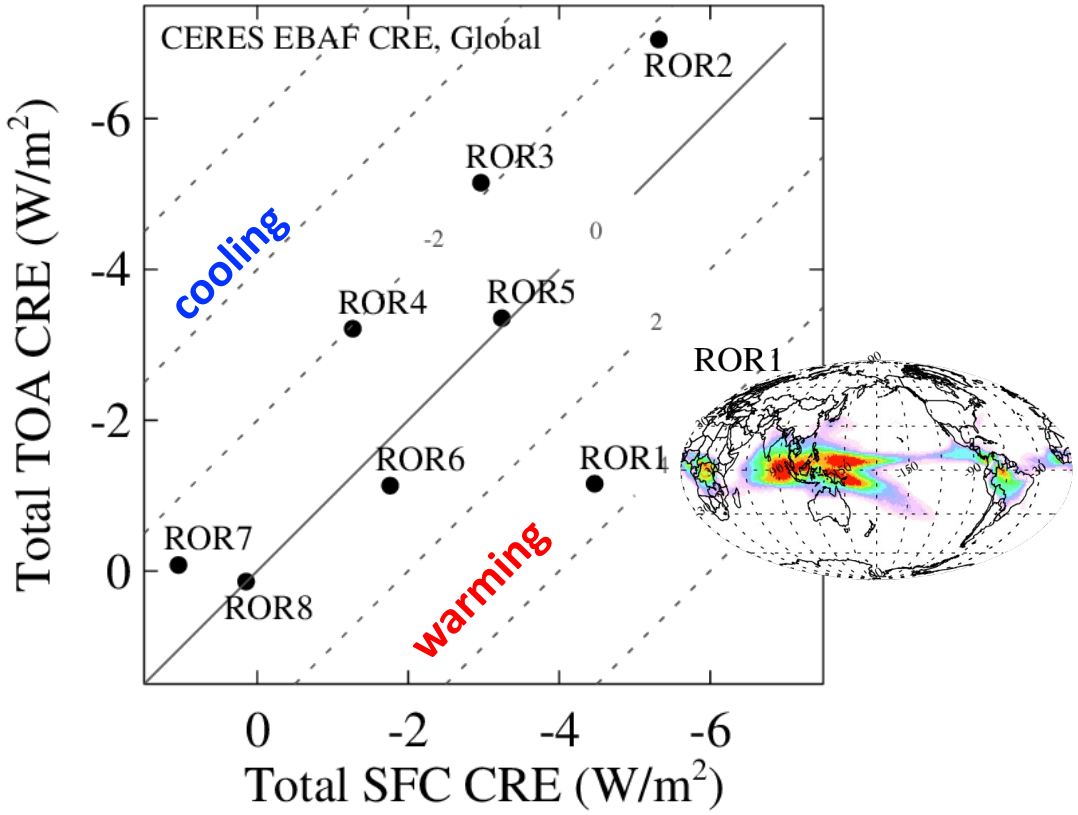
CRE decomposition by ROR

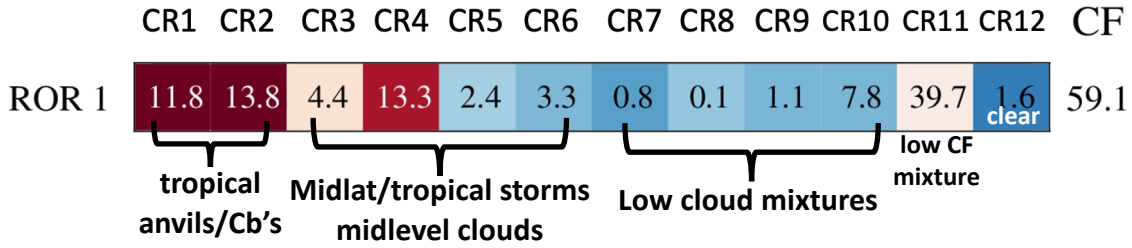
planetary cooling by clouds



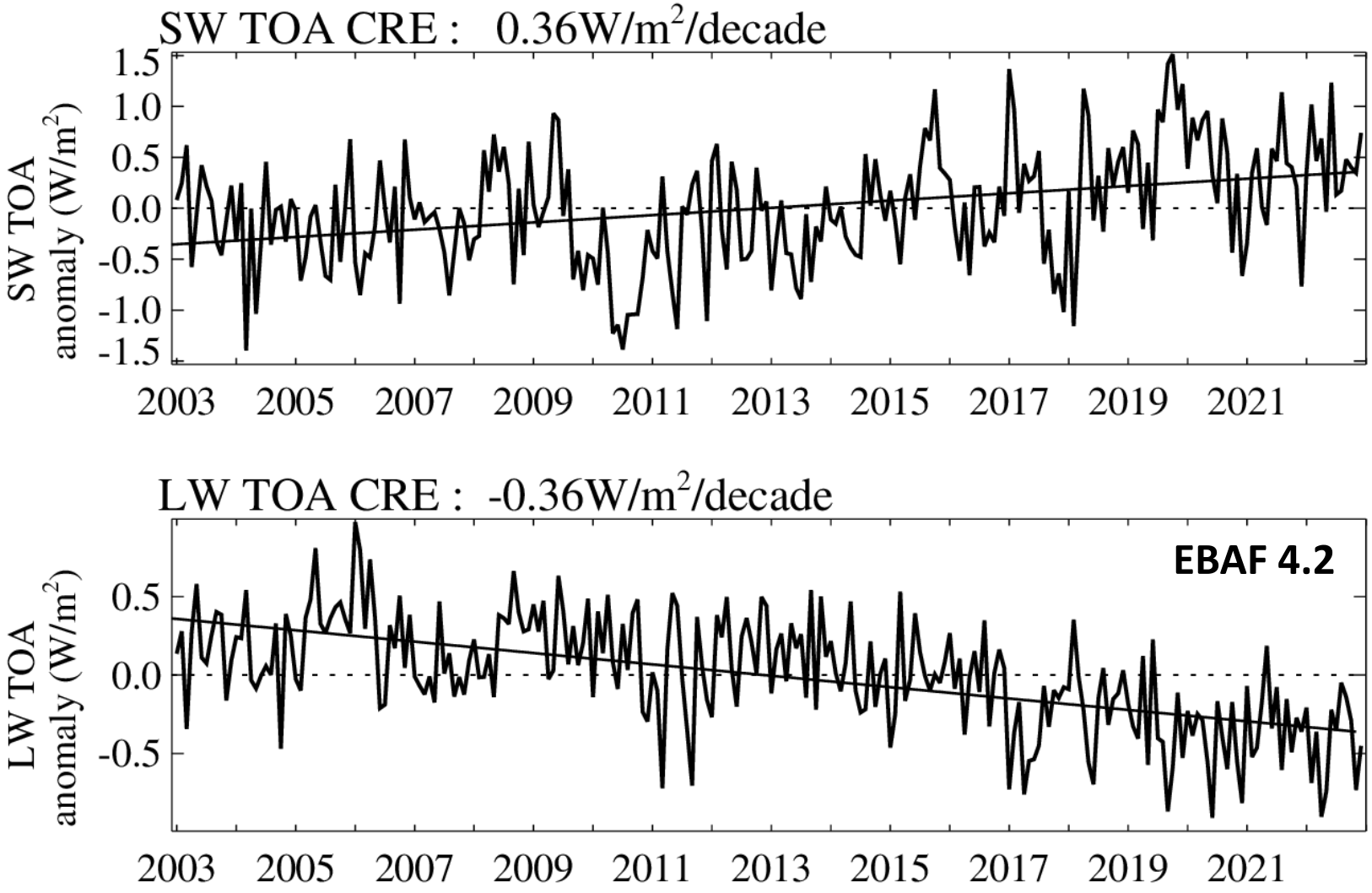


atmospheric warming/cooling by clouds



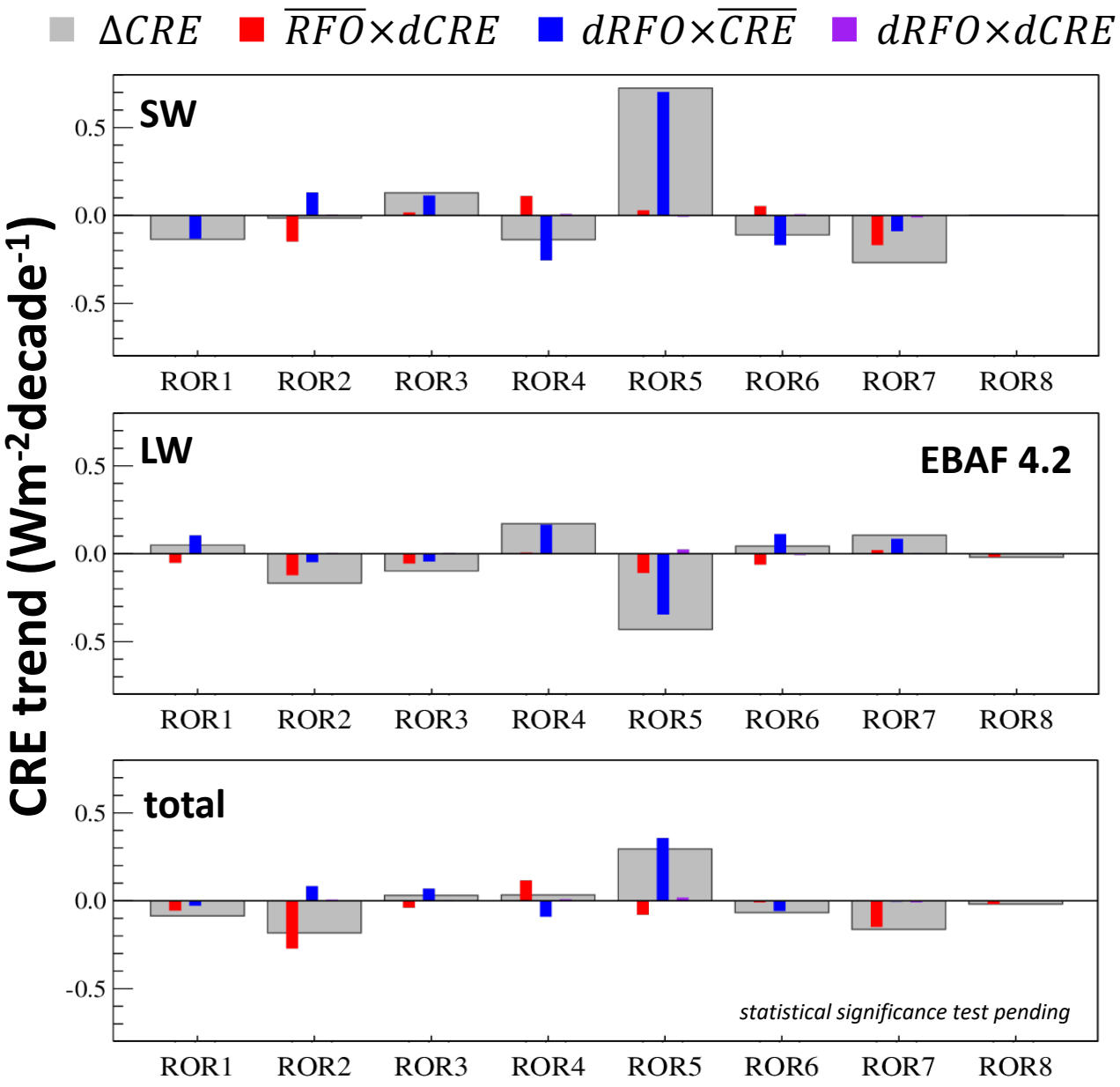


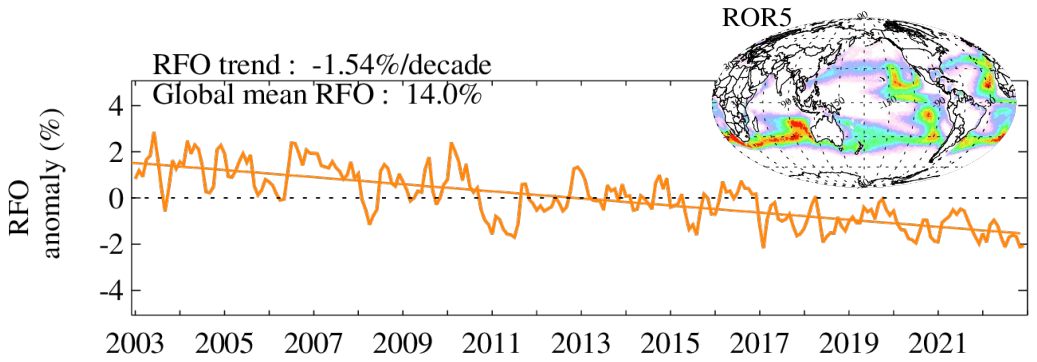
CRE trends

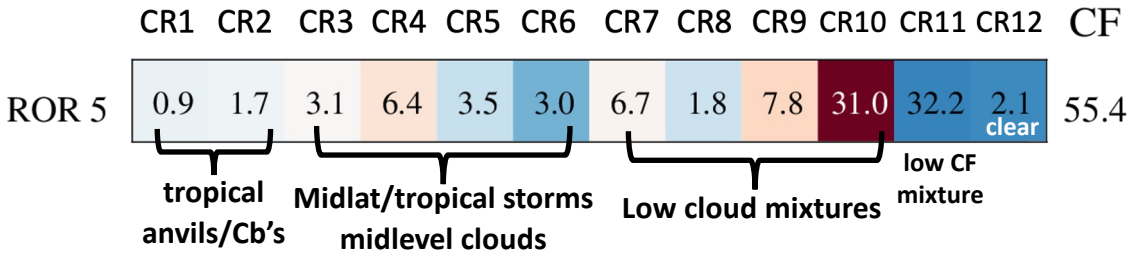


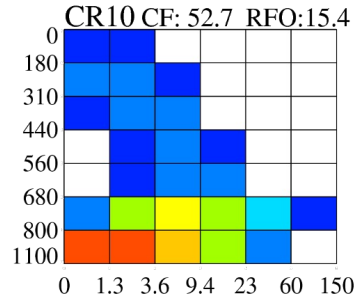
Similar to Raghuraman et al. (2023) [+0.33 Wm^{-2} and -0.35 Wm^{-2}]

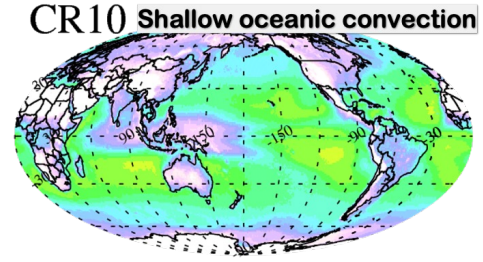
CRE trend decomposition by ROR

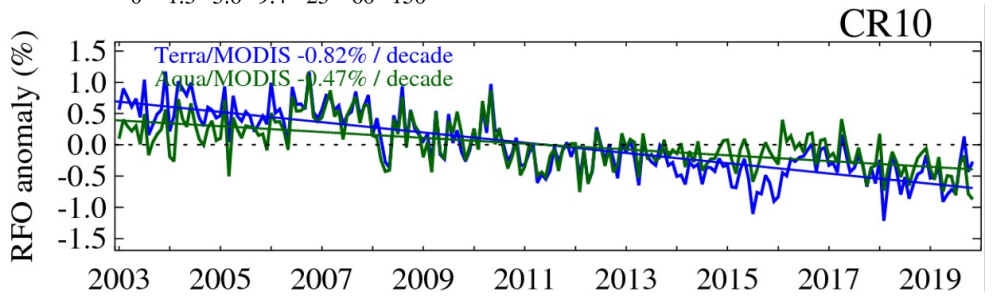










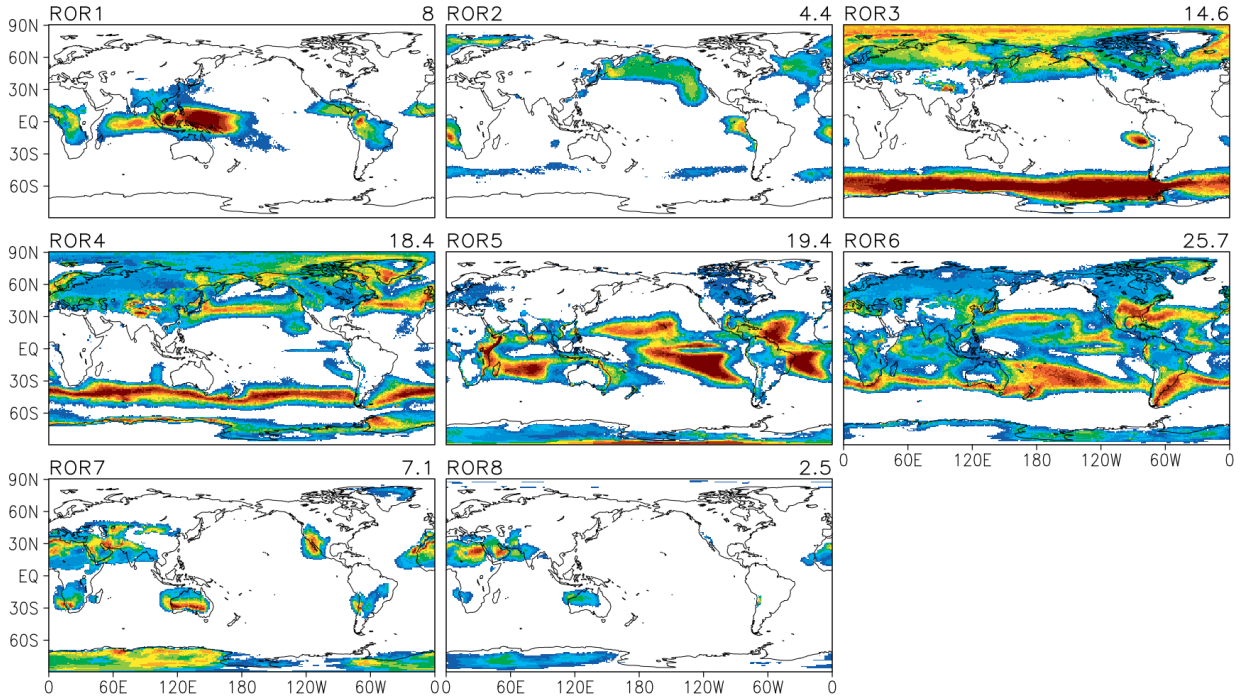


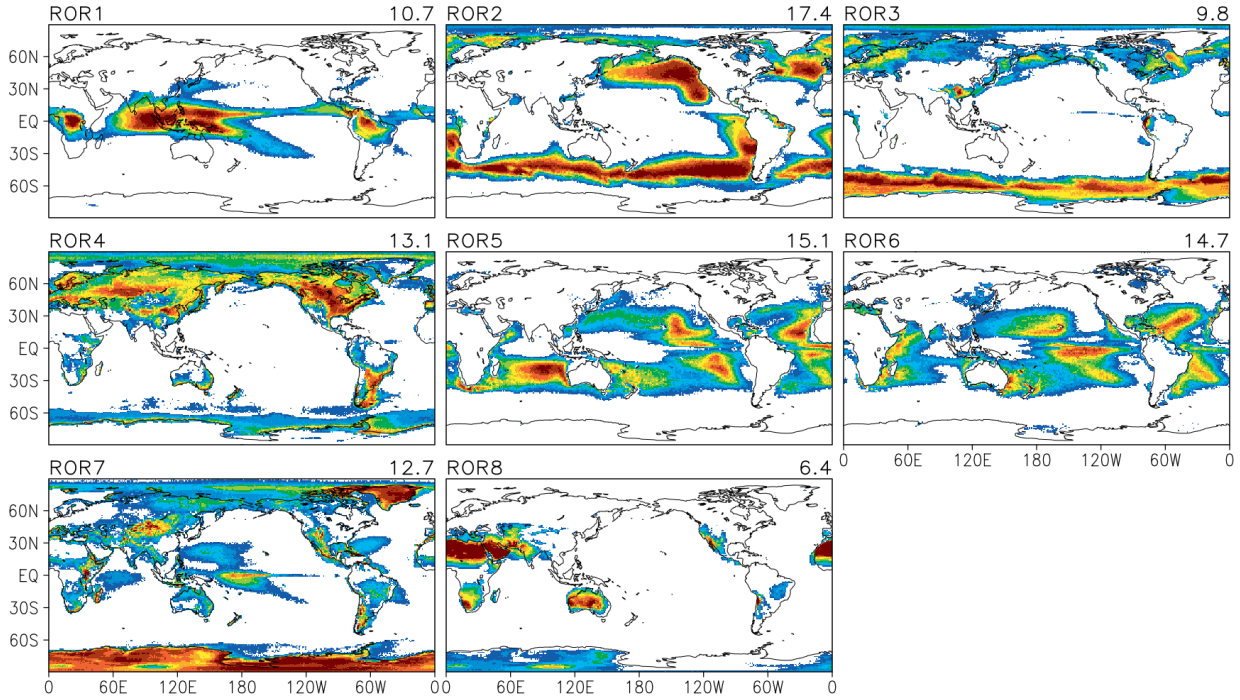
Application: Global Model cloud evaluation

RORs in GFSC's GEOS

- GEOS RORs from free clustering CR RFO histograms
- GEOS CRs from "forced" assignment of CTP-TAU joint histograms

MODIS COSP RORs





Need MODIS simulator to produce joint CTP-TAU histograms

Take-home messages

- We investigated whether meso-scale (~100 km) cloudiness over monthly or longer temporal scales can be organized into a new cloud class/construct which we termed “Regimes of Regimes” (RORs)
- RORs are extracted by classifying the occurrence frequency over a period of time of Cloud Regimes (CRs) which mainly capture daily cloud spatial variability.
  - In our case, RORs were derived from previously available MODIS (MOD08/MYD08) CRs.
  - Can also be derived from FBCT CRs
- The concept can in principle be also be applied to Earth System Models that can produce CRs via the MODIS simulator.
- Climate Data Record datasets (e.g., CERES EBAF, GPCP-monthly) and climate phenomena can be more easily associated with the climatological cloud classes represented by RORs.
- Our first ROR application focused on CERES EBAF mean CRE decomposition and CRE trends.
  - We found weaker SW and LW CRE trends for an ROR with large amounts of the shallow convection CR.
  - The frequency of occurrence of this CR is clearly decreasing over the last 20 years.


Questions?